

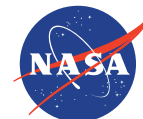


# Thermal and Exported Vibration Characterization of RICOR K508N Cryocooler

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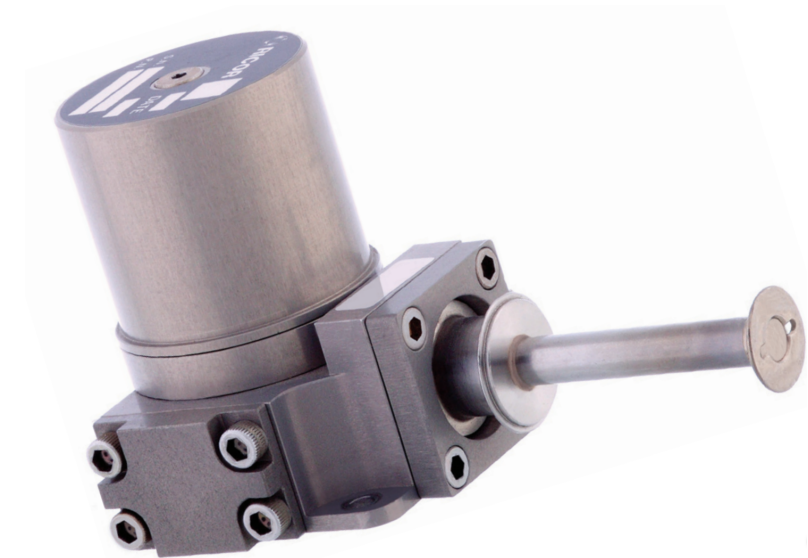
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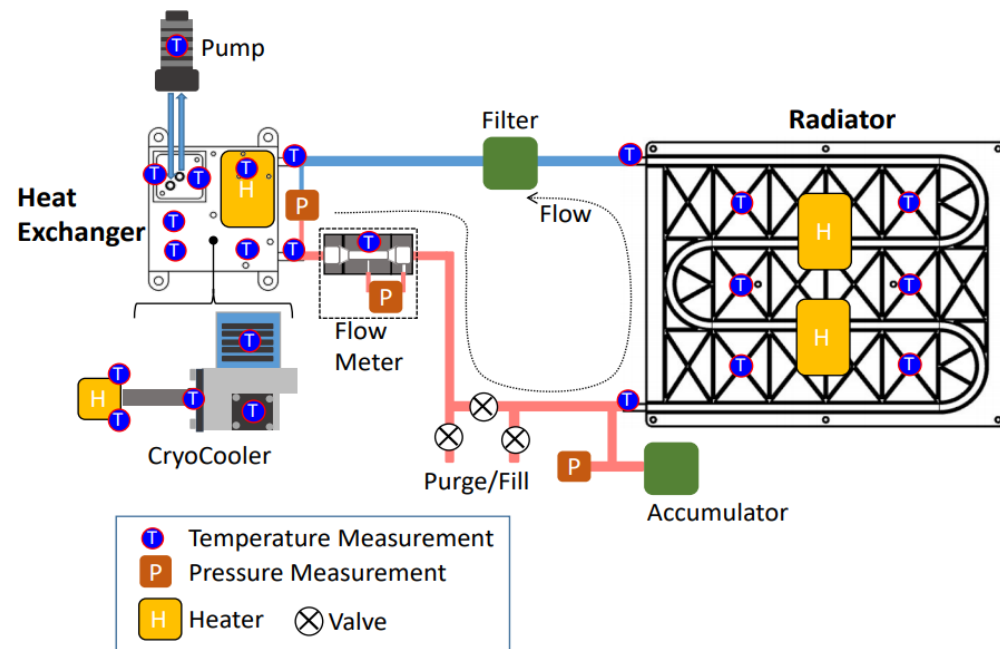
# Overview

- The RICOR K508 has been a reliable cooler for space applications since 1994
  - CheMin, ROSETTA, MRO etc.
  - Stirling cycle cooler
  - 700mW @ 77 K @ 23°C
  - -40°C to 85°C ambient temperature
  - Cooler Weight: 470g
- The K508N is an upgrade on K508
  - Double the reliable operating hours to 20,000
  - K508N is fully interchangeable with K508
- ATACOI, CIRAS and MASPEX will use K508N coolers



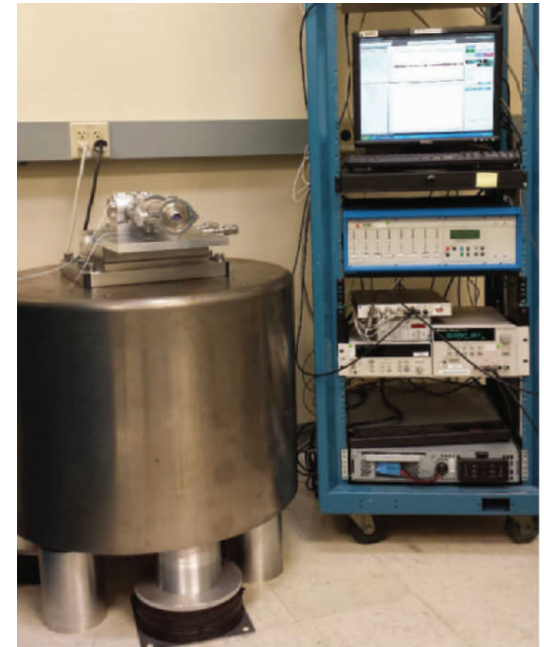
# ATACOI Overview

- Advanced Thermal Architecture for Cryogenic Optical Instruments (ATACOI) is a CubeSat project which aims to advance the TRL of a pumped fluid loop thermal architecture.
  - Utah State University and JPL are Co-investigators
- The heat from a RICOR K508N is rejected to space via a deployable radiator
  - Rotary fluid joint is critical
  - Heat exchanger is additively manufactured to save volume and mass
- Currently, individual components are being validated for a full-scale build and test at JPL.



# Test Plan

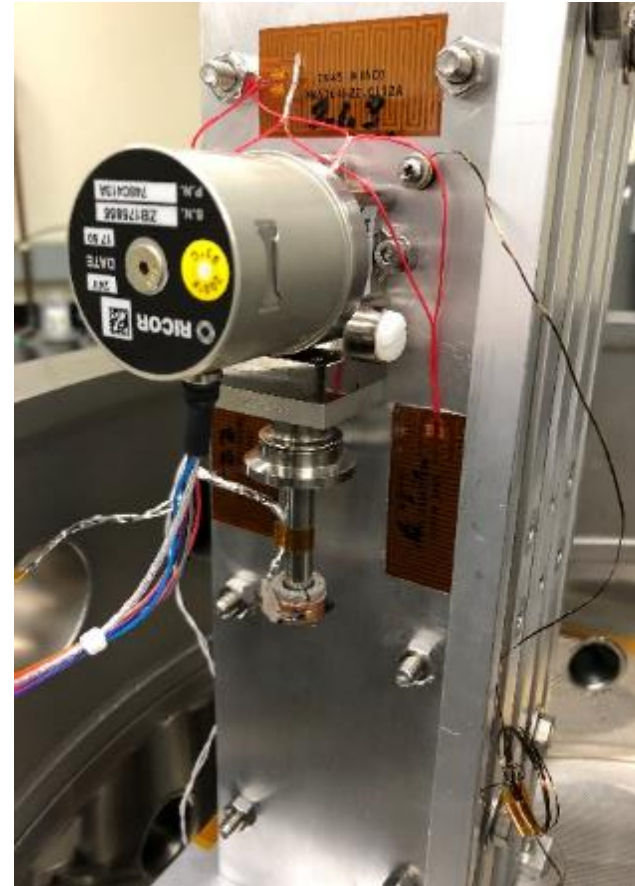
- Four RICOR K508N coolers were tested at JPL
  - Thermal and EFT testing done to advance flight-readiness of hardware
- Thermal tests done in vacuum chamber
  - Control over cold tip heat load and temperature, reject temperature and input voltage
- EFT done on Kistler 9255 Dynamometer



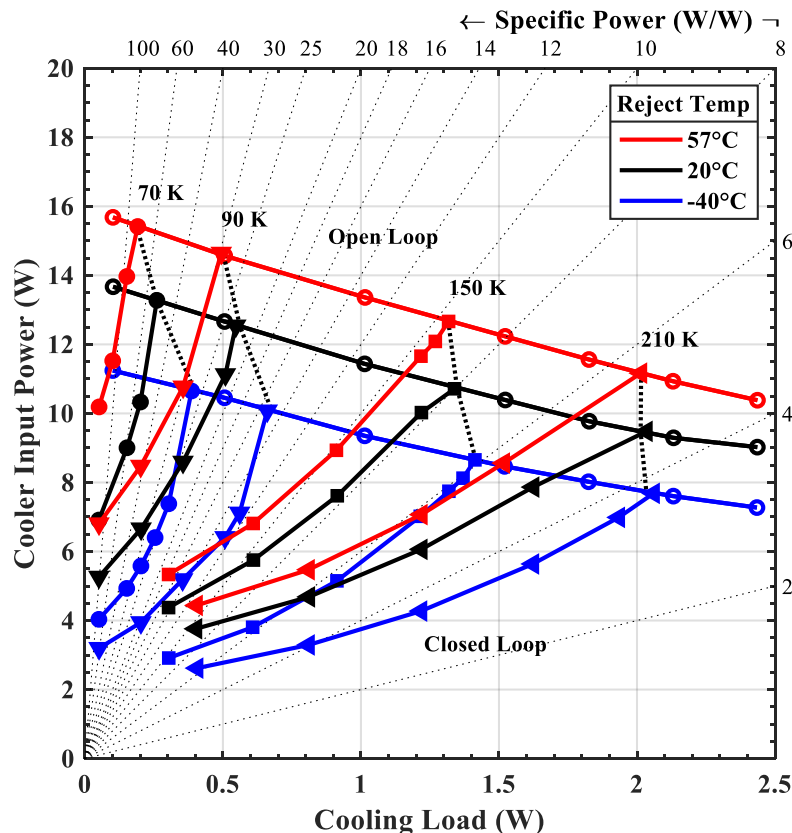
Cooler	Description	Tests Done
ATACOI K508N	COTS Cooler	Thermal and EFT
CIRAS 1 Cooler	Flight Unit 1-Spectrometer	Thermal and EFT
CIRAS 2 Cooler	Flight Unit 2-Focal Plane	Thermal and EFT
MASPEX	EM with IRIS Electronics	EFT only

# Test Setup-Thermal

- FTS RC-211 Chiller and a heater circuit used to control reject temperature.
- Copper block with three silicon diodes and a 1,500 Ohm resistor clamped to cold tip.
- A 10k $\Omega$  potentiometer was added in series with one of the diodes
  - Pot dissipated some of the voltage allowing different setpoints
- Data collection process was automated through a LabVIEW program

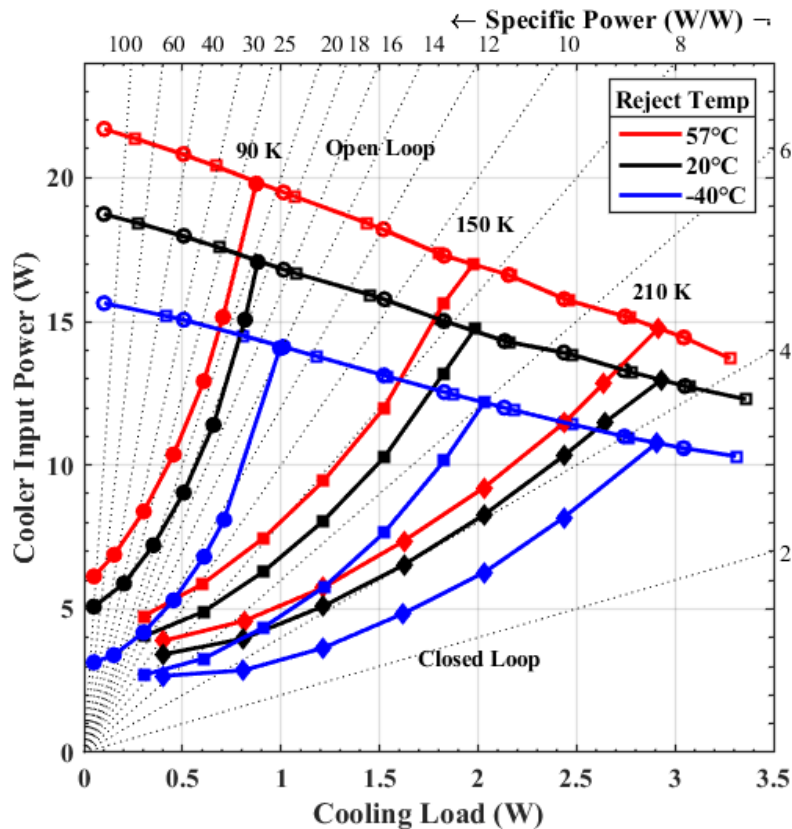


# ATACOI K508N Thermal Testing



- Open and closed-loop data collected
  - Nominal input of 24 VDC and 35 bar fill pressure
  - Cold tip: 70 K to 240 K
  - Reject: -40°C, 20°C, 57°C
- All data fit into a 65 coefficient equation that can predict the coolers performance reliably
  - $P_{in} = f(T_{CT}, T_{rej}, Q_{in})$
  - $Q_{in} = f(T_{CT}, T_{rej}, P_{in})$
- Maximum relative error for predicting power at 5%
- These equations can be using in conjunction with thermal model to predict performance.

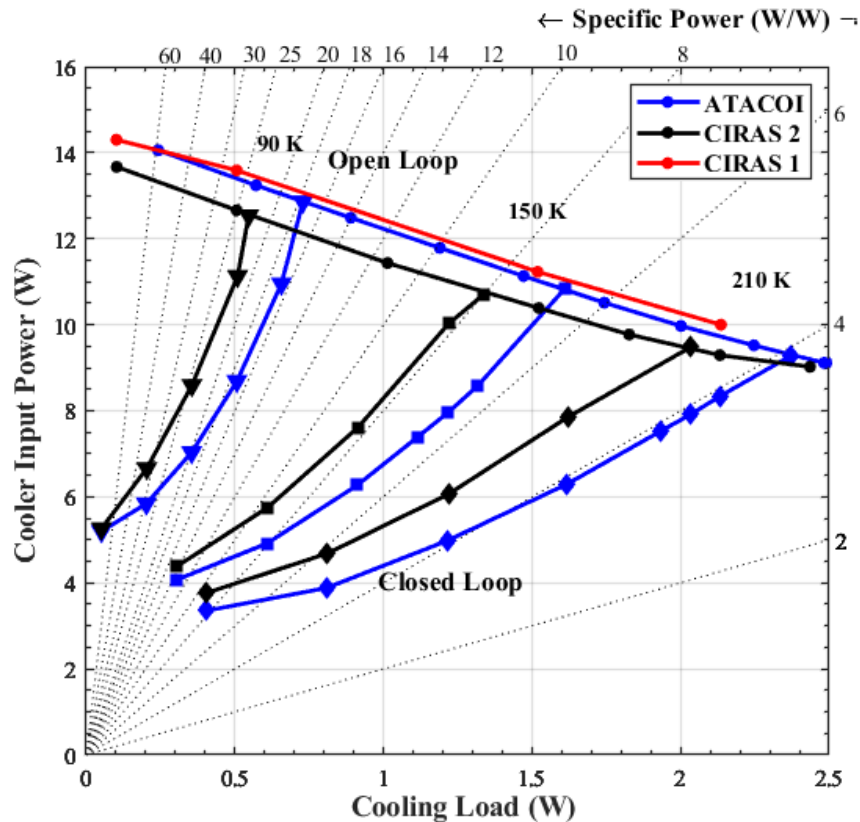
# CIRAS K508N Thermal Testing



\*Data is for CIRAS 2 (SN 57-07750)

- Open and closed-loop data collected
  - Two flight quality K508N's
  - Input of 15 VDC
    - Nominal is 12 VDC
  - 40 bar fill pressure and “High” frequency motor used
  - Reject: -40°C, 20°C, 57°C
  - Cold Tip: 90 K to 240 K
- Coolers are modified to provide more cooling power
  - Cost of higher charge pressure is a shorter life.

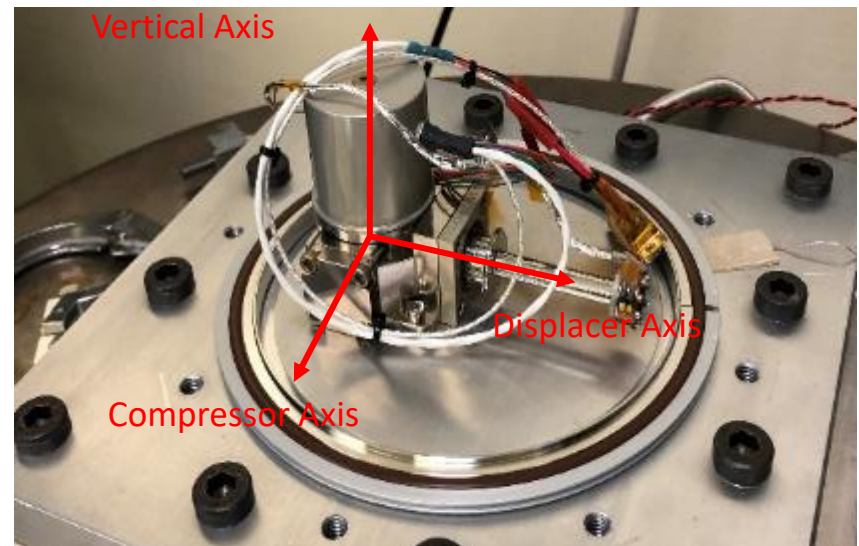
# ATACOI and CIRAS Comparison



- Comparison is made for data taken at nominal inputs for all coolers
  - 24 VDC for ATACOI
  - 12 VDC for CIRAS
- CIRAS coolers are in fact more efficient for a given cooling load
  - At 20°C reject, 90 K cold tip, 0.5 W load input power is 8.7 W vs. 11.1 W
  - 22% reduction
- However, the unit-to-unit variability is not well understood
  - Flight quality K508 coolers for CheMin showed a 9% performance improvement from worst to best cooler in a lot of six coolers.

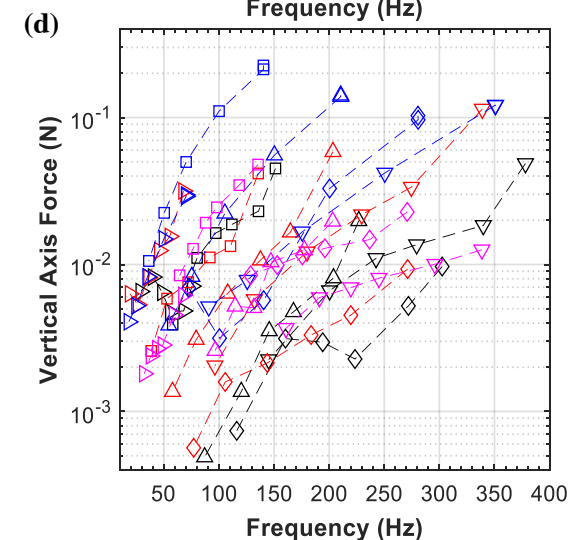
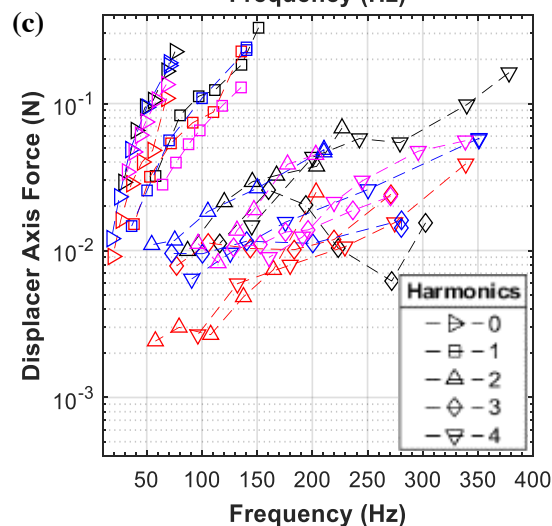
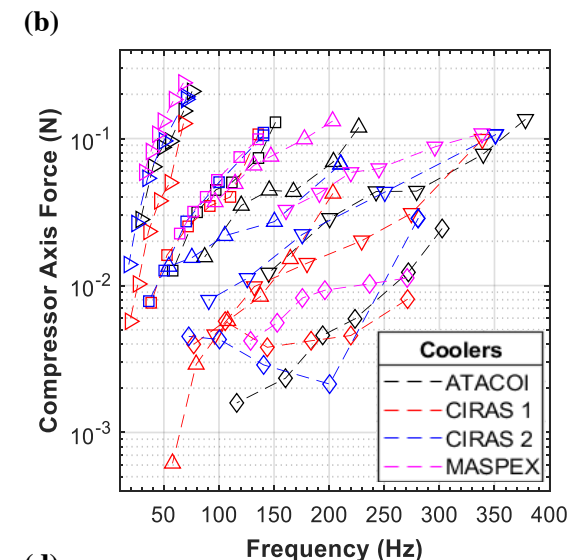
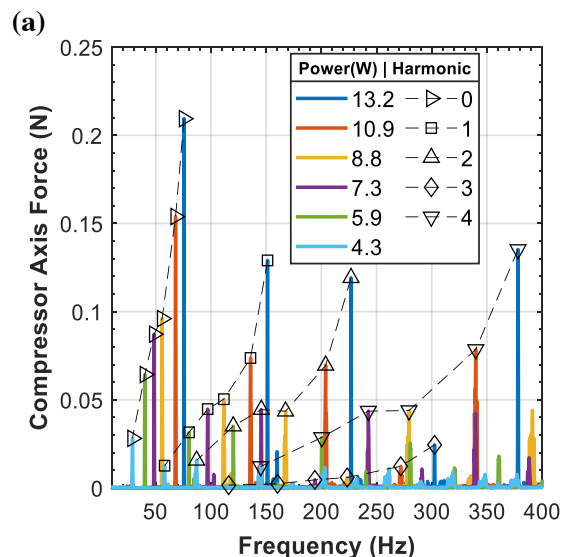
# Test Setup-Exported Force Testing

- All coolers were tested in a vacuum enclosure on a Kistler Model 9255 dynamometer
  - Reject temperature did not exceed 30°C
- Input power was controlled by adjusting the closed-loop setpoint
- MASPEX cooler has custom electronics built by IRIS Technologies.
- Vacuum hose removed during data collection



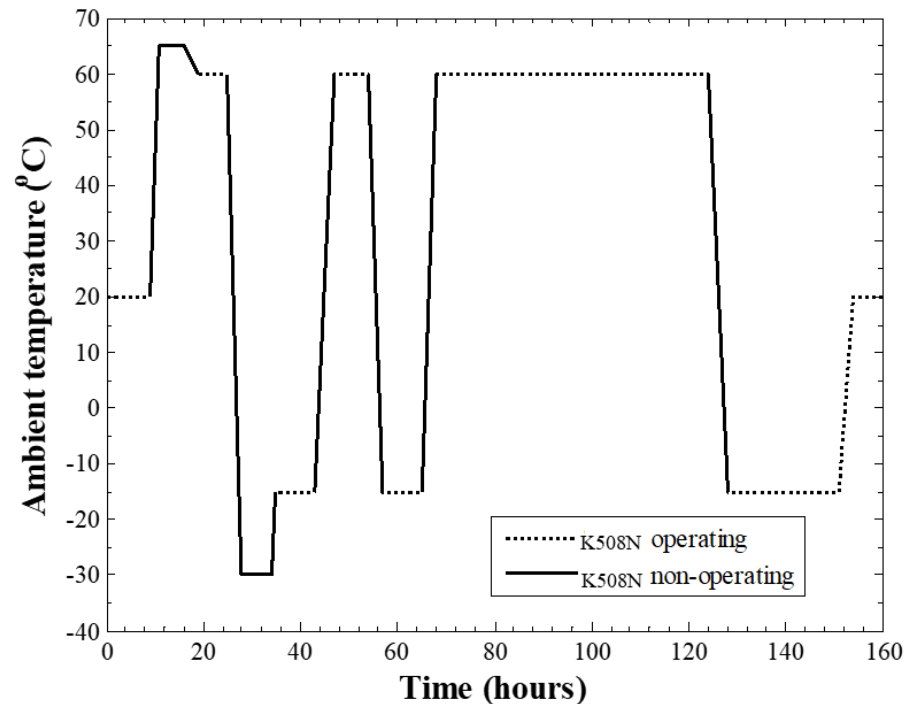
# EFT Results

- (a) shows the compressor axis force for the ATACOI cooler at different powers
  - Harmonics are marked
- (b),(c),(d) show the force vs. frequency for all coolers in the three axes
- Dominant forces are in the displacer and compressor axis
- At higher harmonics the exported forces show less agreement
  - Could be due to displacer rubbing on inside of cold finger
  - Another example of unit-to-unit variability

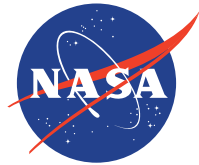


# Protoqual Thermal Cycling of ATACOI K508N

- Per JPL Environmental Requirements the K508N must be thermally cycled to advance its TRL
  - 72 hours and three starts at hot-op
  - 24 hours and three starts at cold-op
  - Six hours at not non-op
  - Six hours at cold non-op
  - Ramp rate not to exceed 5°C/min
- Test temperatures set as close to hardware limits as possible
- The cooler performed nominally throughout the test
- Helium leak rate remained constant at  $2 \times 10^{-8}$  Torr L/s
  - 1.2% drop in charge over 5 years



	Hot Non-Op	Hot Op	Cold Op	Cold Non-Op
Test Temperatures	70°C	70°C	-40°C	-50°C
Hardware Limits	85°C	85°C	-40°C	-55°C



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